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DETECTION SUITABLE WAVELENGTH FOR MATURITY STAGES OF ORANGE FRUITS USING SPECTRAL ANALYSIS

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ABSTRACT

The aim of this study was measuring and determination of the optical properties of maturity stages of orange fruits (Abo Sora variety) using visible light (VIS) and invisible lights (UV and IR). Three light regions, ultraviolet (350 – 400 nm), visible light (400-700nm), and near infrared (700-1000 nm) wavelengths were used. Obtained results were summarized as follow: (a) Reflection intensities using ultraviolet light with wavelengths from 350 to 400 nm from orange fruit of maturity stages ranged between 173.8 and188.80 a.u. Meanwhile, absorption intensities ranged between 174.29 and188.80 a.u. , b) Reflection intensities of infrared wavelengths from 700 to 1000 nm from orange fruits of maturity stages ranged between 166.72 and 277.73 a.u. Meanwhile, absorption intensities were ranged between 172.01-290 a.u. Therefore, there are no big differences in reflection and absorption intensities values of ultraviolet and infrared wavelengths for different maturity stages of orange fruit, Therefore, measurements of reflection and absorption intensities using ultraviolet and infrared were negligible; c) The peak reflection intensities using visible light were found 1051.83, 1361.21, 1959.85, 2461.68, 3760.96 and 3610.12 a.u at wavelengths of 540, 545, 550, 560, 570, 580 nm, respectively. Meanwhile, the peak absorption intensities were found 598.12, 980.79, 1959.73, 2615.14, 3189.04 and 3840.15 a.u at wavelengths 545 , 550, 560, 570, 580, and 585 nm for green, light green , very light green and turning, yellow, and orange maturity stages of color orange fruits, respectively., e) It is possible to use of 540, 545, 550, 560, 570, 580 nm as a source of peak reflection, while using 545 , 550, 560, 570, 580, and 585 nm as a source of peak absorption for green, light green , very light green and turning, yellow, and orange maturity stages of color orange fruits, respectively, to detect maturity stages of orange fruits., and f) Using light spectrum with wavelengths from 540 to 585 nm is preferable in grading orange fruit as a source of reflection and absorption peaks during maturity stages and can automatically control the process.

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INTRODUCTION

Non-destructive quality evaluation of food products is important and very vital for the food and agricultural industry. The concept of quality is closely related to the ability of the product to satisfy the consumer needs.

Ali et al. (2012) mentioned that machine vision and image processing are methods which have various applications in agriculture, including volume determination, grading and diagnosing surface damages of products. If lighting or camera height is not suitable, processing by machine vision will not have acceptable performance. This was tested using oranges.

Iqbal et al. (2012) said that post harvest sorting and grading of fruits is a difficult and labour intensive component of the commercial fresh fruit market. Although mechanical equipment are available to perform operations like sorting and grading of fruits, manual effort is still indispensable. Packing and sorting by visual inspection as the fruit passes on a conveyor belt and mechanical sorting is limited to size sorting.

Barrett et al. (2010) showed that the color, flavor, texture, and the nutritional value of fresh-cut fruit and vegetable products are factors critical to consumer acceptance and the success of these products. Both instrumental and sensory measurements were used to determine this critical quality attributes. The effects of fresh-cut processing techniques and treatments on sensory quality, including the appearance, texture, flavor (taste and aroma) of vegetables, and fruits are detailed.

Shewfelt (2000a) mentioned that the color and appearance attract the consumer to a product and can help in impulse purchases. At the point of purchase the consumer uses appearance factors to provide an indication of freshness and flavor quality. External appearance of a whole fruit is used as an indicator of ripeness.

Crisosto et al. (2003) indicated that the consumers have a preferred color for a specific item. Bananas are supposed to be yellow with no brown spots, tomatoes red not orange, cherries red not yellow, and kiwifruit green-fleshed not yellow. With the exception of the outside of a few fruits like pears and kiwifruit, fresh fruits and vegetables should not be brown.

Shewfelt (2003) mentioned that the white blush in cut carrots is a quality defect. Russet (brown) spotting and brown stain (two separate disorders) are undesirable visual defects in lettuce. Visible wilting in lettuce and celery and shriveling in fruits reduce consumer acceptability. Yellowing in green vegetables due to loss of chlorophyll is unacceptable. Less intensity of color indicates lack of ripeness in fresh-cut fruits. Browning is a serious quality defect in fresh-cut fruits.

Gross (1987) mentioned that the cones may be further divided into receptors sensitive to red (long wavelength), green (medium wavelength), and blue (short wavelength) light. The integrated, trichromatic response of the red, green, and blue-sensitive cones stimulates how we perceive color. Each pigment in fruits and vegetables corresponds to a primary hue—red, blue, and green.

Beaulieu and Lea (2007) mentioned that the harvest maturity significantly affects the level of flavor volatiles recovered in fresh-cuts from soft-ripe versus firm-ripe mangos , and 1/4-, 1/2-, 3/4-, and full-slip "Sol Real" cantaloupe . Cantaloupe fruit harvested at different maturity stages deliver stored cubes differing significantly in quality, flavor, textural attributes, and volatiles. In general, cubes prepared with less mature fruit, which are excessively firm, lack flavor volatiles and have inferior, less acceptable sensory attributes.

Muhammad et al. (2001) mentioned that the useful storage life of harvested fresh produce can often be extended by a decrease in the $O2$ concentration and an increase in the $CO2$ content of the surrounding atmosphere, provided such changes are within specific limits for each commodity. Post harvest losses in citrus fruits have been observed too much due to which fruit loses its quality.

Hahn (2002) said that the size, which is the first parameter identified with quality, has been estimated using machine vision by measuring area, perimeter or diameter. Color is also an important quality factor that has been widely studied.

Dobrzanski and Rybczynski (2002) mentioned that some fruits have one colour homogeneously distributed on the skin surface, which we call primary colour. The averaged surface colour is a good quality indicator for these fruits. However, other fruits (e.g. some varieties of peaches, apples, tomatoes) have a secondary colour that can be used as a good indicator of maturity.

Penman (2002) mentioned that in oranges, peaches and apples there is an interest in detecting long stems in order to avoid damage to other fruit, or because their absence could imply a quality loss. Several solutions have been proposed to determine the position of the stem, such as: the use of structured lighting to detect concavities in apples; colour segmentation techniques to differentiate the calyx and stem in citrus fruits; or the study of light reflection in apples.

The objectives of this study were:

1- Measuring and determination of peak reflection intensities and absorption of orange maturity stages using different ultraviolet, visible, and infrared wavelengths using light spectrum, to detect suitable wavelength for each maturity stage of orange fruits,

2- Possibility of using suitable wavelength to determine harvesting time and grade orange fruits according to color, to increase quality of orange fruits for exportation, which give high reflection and absorption intensities from fruit surface, and

3- Possibility of using visible light for designed and fabricated machine of sorting and grading to handle ripe orange for national and international trades.

MATERIAL AND METHODS

The present study was executed in the Laboratory of Laser Applications in Agricultural Engineering at the National Institute of Laser Enhanced Science (NILES), Cairo University, to detect suitable wavelength from visible and invisible lights (Ultraviolet, Visible, and Infrared wavelengths) to measure the peak of optical properties at reflection and absorption intensities of maturity stage of orange fruit during season 2012. The orange fruits were collected during period of sixty days, each maturity stage after 10 days, from 20 September to 25 November.

Sample preparation: A random sample from orange fruits (Abo Sora variety) (five hundred fruits) was obtained from private farms at Kaluobia Governorate. The orange fruits were exposured by three a sources of in light spectrum: ultraviolet, visible and infrared wavelengths to determine optical reflections and absorptions of orange fruits at different maturity stages. The sample was classified into six mature stages according to colors using image analysis technique. Some physical properties for orange fruits are shown in Table (1).

Table (1): Some physical properties for orange fruits.

Items	Value
Large diameter, cm	8.16
Small diameter, cm	7.50
Thickness of skin, cm	0.25
Orange mass, g	200
Volume , cm3	85
Orange juice, %	35

Digital vernier caliper: The caliper has an accuracy of 0.01 mm. It was used to measure the dimensions for the individual fruits.

Digital balance: Source of manufacture: Germany; Model: SBA 51; and accuracy 0.01g. It was used to determine the mass of individual fruits.

Setup: The experimental setup consisted of USB4000 spectrometer, visible and invisible lights, holders and personal computer with spectrasuite software. Specifications of spectrophotometer are illustrated in table (2) and Fig. (1)

Holders: Holders were designed and constructed of copper to hold light source and fiber optics.

Computer: Utilized the software, which shows the results of optical analysis of oils (Spectra suite of Ocean Optics Software).

Measuring optical characteristics:

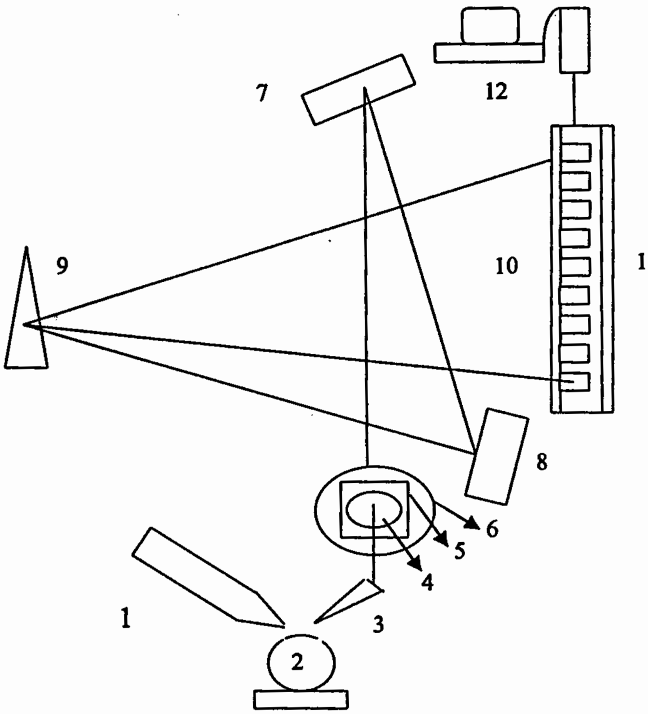
- Reflection light from orange fruit was towards the input fiber to enter the optical bench through this connector.
- The amount of light that enters the optical bench and controls spectral resolution using a rectangular aperture with size (from 5 to 200 µm), which is mounted directly behind the connector.
- Light passes through the filter before entering the optical bench to restrict radiation to certain wavelength regions, before deterring wavelength regions.
- Focused light enters the optical bench towards the grating of the spectrometer using collimating mirror.

- Diffracted light from the collimating mirror and directs the diffracted light onto the focusing mirror for gratings which are available in different groove densities, allowing to specify wavelength coverage and resolution in the spectrometer.
- Received light reflected from the grating, focuses first-order spectra onto the detector plane using focusing mirror.
- Collected light received from the focusing mirror or L4 detector collection lens converts the optical signal to a digital signal Using detector. Each pixel on the detector responds to the wavelength of light that strikes it, creating a digital response.
- The spectrometer then transmits the digital signal to the SpectraSuite application (software programme) in personal computer, to give reflection and absorption intensities data and curves.

Table (2): Specifications of USB4000 spectrometer, made of USA.

Specification	**Value**
Dimensions, mm	89.1 x 63.3 x 34.4
Weight , g	190
Power consumption	250 mA at 5 VDC
Detector	3648-element linear silicon CCD array
Detector range , nm	200-1100
Gratings	14 gratings available
Entrance aperture	5, 10, 25, 50, 100 or 200 μm wide slits
Order-sorting filters	Installed longpass and bandpass filters
Focal length	42 mm input; 68 mm output
Optical resolution	Depends on grating and size of entrance aperture
Stray light	<0.05% at 600 nm; <0.10% at 435 nm
Dynamic range	3.4 x 10^6 (system); 1300:1 for a single acquisition
Fiber optic connector	SMA 905 to single-strand optical fiber (0.22 NA)
Data transfer rate	Full scans into memory every 4 milliseconds
Integration time	3.8 ms to 10 seconds (detector's limit is ~15 sec)
Interfaces	USB 2.0, 480 Mbps
Operating systems	Windows 98/Me/2000/XP, Mac OS X, and Linux.

a) Photo of spectrum setup.



b) Diagram of spectrum setup

1- Light source, 2- Sample, 3- Fiber optics, 4- Connector, 5- Slit, 6-Filter
7- Collimating Mirror, 8- Grating, 9- Focusing Mirror, 10-L4 detector
Collection Lens, 11-Detector (UV or VIS or IR), and 12-Personal computer with SpectraSuite software.

Fig (1): Diagram and photo of specifications of USB4000 Spectrometer.

RESULT AND DISCUSSION

Ultraviolet light for orange fruits at different maturity stages:

Fig. (2) shows the reflection intensity of ultraviolet light with different wavelengths from orange fruits at different maturity stages.

The wavelengths of ultraviolet bands ranged between 350 and 400 nm. The obtained results exposure of orange fruit for ultraviolet wavelengths from 350 to 400 nm showed that the reflection intensity ranged between (173.88 -184.55 a.u.), (174.72 -184.83 a.u.), (175.28 - 188.80 a.u.), (177.04 - 187.85 a.u.), (178.49 - 191.86 a.u.), and (177.12 - 188.62 a.u.) for green, light green, very light green, turning, yellow, and orange colors of orange fruit, respectively.

That means that there is no big difference in reflection intensities of ultraviolet from different maturity stages, because it ranged between 173.8 and 188.80 a.u. for ultraviolet wavelengths from 350 to 400 nm.

Fig. (3) shows the absorption intensity of ultraviolet light from orange fruits at different maturity stages, by using the same ultraviolet wavelengths in order to measure absorption intensities in orange fruits at different maturity stages.

Absorption intensity ranged between (175.32 -184.18 a.u.), (175.18 - 192.51 a.u.), (174.29 – 188.32 a.u.), (175.52 – 188.21 a.u.), (175.25 – 188.80 a.u.), and (175.28 - 188.44 a.u.) for green, light green, very light green, turning, yellow, and orange color of orange fruit, respectively.

It is noticed that there is no big variance in absorption intensities of ultraviolet from different maturity stages, because it ranged between 174.29 and 188.80 a.u. for ultraviolet wavelengths from 350 to 400 nm

That means that the reflection and absorption intensities didn't have clearly variance between them. Therefore, using ultraviolet wavelengths from 350 to 400 nm to measure reflection and absorption intensities was insignificant.

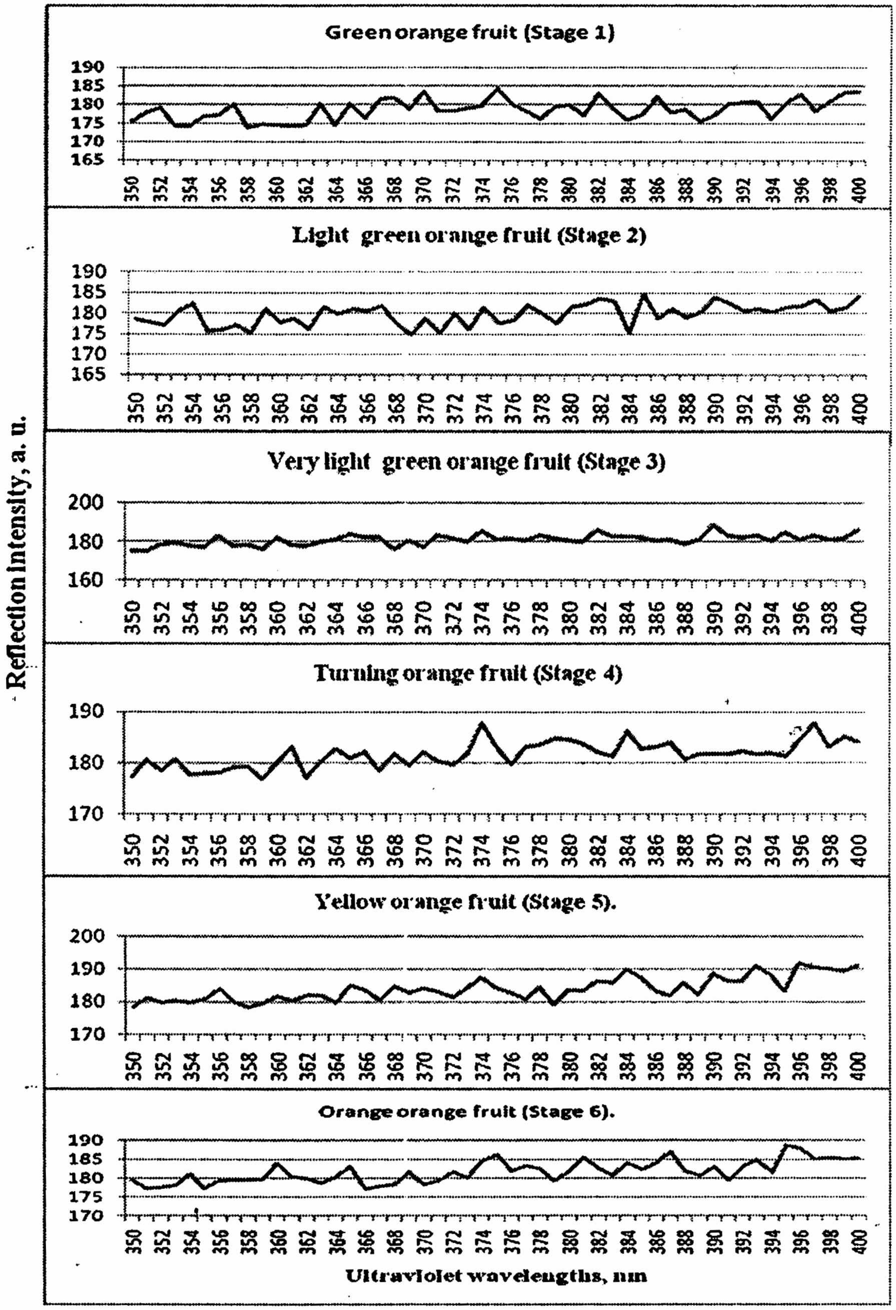


Fig. (2) : Reflection intensity of ultraviolet light from orange fruits at different maturity stages.

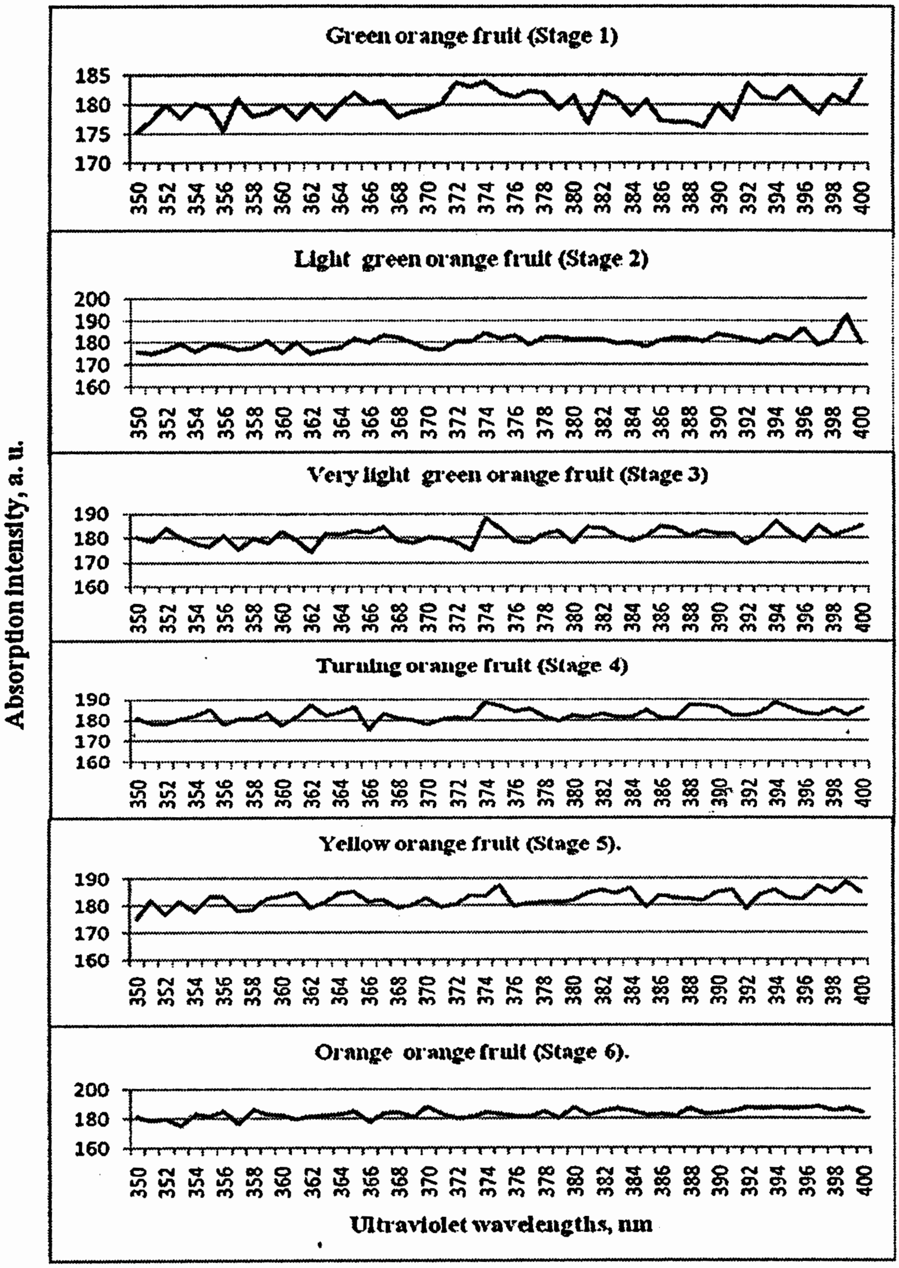


Fig. (3) : Absorption intensity of ultraviolet light from orange fruits at different maturity stages.

Infrared light for orange fruits at different maturity stages:

Fig. (4) shows the reflection intensity of infrared light from orange fruits at different maturity stages. The wavelengths of infrared bands ranged between 700 and 1000 nm. The obtained results exposure of orange fruit for infrared wavelengths showed that the reflection intensity ranged between (168.85 -222.75 a.u.), (172.88 -257.44 a.u.), (166.72 – 307.34 a.u.), (170.13 – 253.46 a.u.), (173.58 – 277.73 a.u.), and (173.72 – 276.78 a.u.) for green, light green, very light green, turning, yellow, and orange color of orange fruit, respectively.

That means that there is no big variance in reflection intensities of infrared light from different maturity stages, because it ranged between 166.72 and 277.73 a.u. for infrared wavelengths from 700 to 1000 nm

Fig. (5) shows the absorption light intensity of infrared light from orange fruits at different maturity stages. Meanwhile, by using the same infrared wavelengths to measure absorption intensities in orange fruits at different maturity stages, the figure (5) indicated to absorption intensity ranged between (172.01 -206.00 a.u.), (173.78 – 222.54 a.u.), (173.88– 248.66 a.u.), (173.96 – 277.28 a.u.), (168.58 – 273.58 a.u.), and (173.69 – 290.00 a.u.) for green, light green, very light green, turning, yellow, and orange color of orange fruit, respectively. It noticed that there is no big variance in absorption intensities of infrared light from different maturity stages, because of it was ranged between 172.01-290 a.u. for infrared wavelengths from 700 to 1000 nm

That means that the reflection and absorption intensities didn't have clearly variance between them. Therefore, using infrared wavelengths from 700 to 1000 nm during measure reflection and absorption intensities was insignificant.

The results showed that the reflection and absorption intensities were obtained at using ultraviolet and infrared wavelengths didn't have big variances. Therefore, it doesn't possible to use the wavegths 350 – 400nm (ultraviolet light) and 700 – 100 nm (infrared light) as detection the quality of orange fruit at different maturity stage. Also, it doesn't use in sorting and grading machine as a detector of optical properties of fruits.

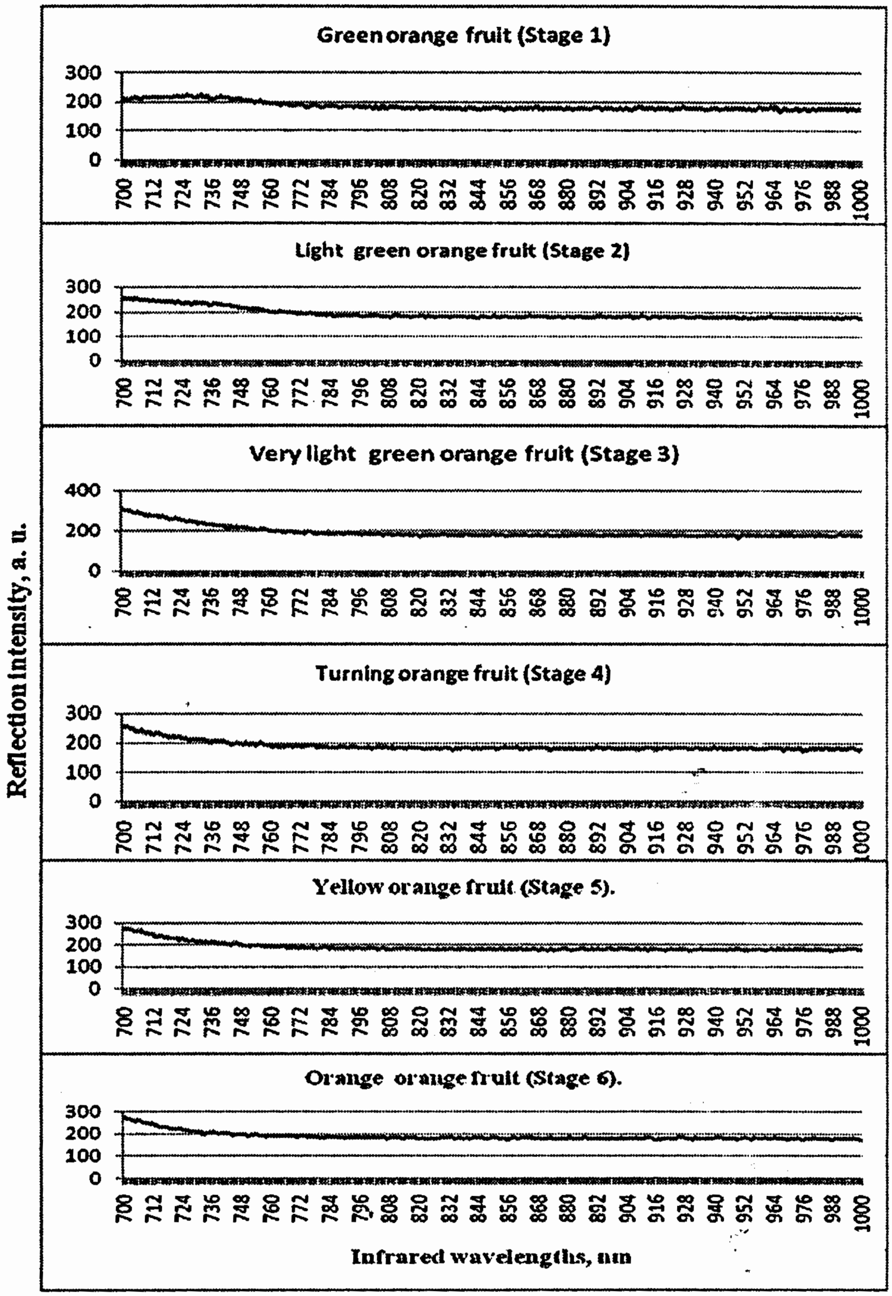


Fig. (4) : Reflection intensity of infrared light from orange fruits at different maturity stages.

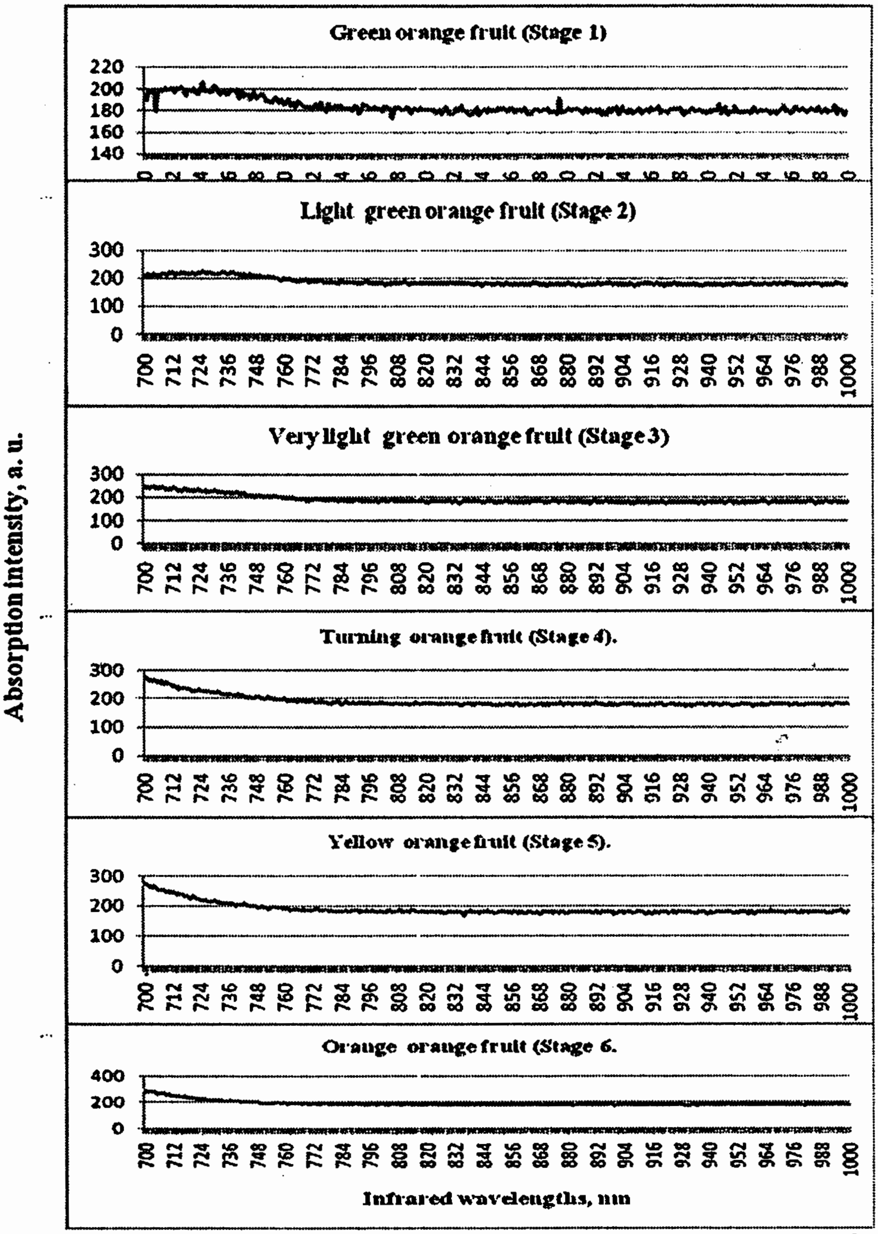


Fig. (5) : Absorption intensity of infrared light from orange fruits at different maturity stages.

Visible light for orange fruits at different maturity stages:

Figs (6 and 7) showed the reflection intensity of visible light with different wavelengths from orange fruits at different maturity stages. It is noticed that the peak reflection and absorption intensities was found, at exposure the orange fruits for wavelengths of visible lights, which ranged between 400 – 700 nm.

During exposure the orange fruits of first maturity stage has green color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 1039.24 and 1040.02 a.u. at wavelength 539 and 541nm, respectively.

Meanwhile, it was found the peak (1051.83 a.u) of reflection intensity at wavelength of 540 nm. Also, it was found the absorption intensity from the same stage of orange was found around 593.92 and 592.09 a.u. at wavelength 544 and 546 nm, respectively. Meanwhile, it was found the peak (598.12 a.u) of absorption intensity at wavelength of 545 nm .

During exposure the orange fruits of second maturity stage has light green color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 1352.98 and 1358.42 a.u. at wavelength 544 and 546 nm, respectively. Meanwhile, it was found the peak (1361.21 a.u) of reflection intensity at wavelength 545 nm. Also, it was found the absorption intensity from the same stage of orange fruits was found around 979.76 and 973.55 a.u. at wavelength 549 and 551 nm, respectively. Meanwhile, it was found the peak (980.79 a.u) of absorption intensity at wavelength of 550 nm .

During exposure the orange fruits of third maturity stage has very light green color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 1955.57 and 1953.85 a.u. at wavelength 549 and 551nm, respectively. Meanwhile, it was found the peak (1959.85 a.u) of reflection intensity at wavelength of 550 nm. Also, it was found the absorption intensity from the same stage of orange fruits was found around 1945.71 and 1935.07 a.u. at wavelength 559 and 561nm, respectively. Meanwhile, it was found the peak (1959.73 a.u) of absorption intensity of at wavelength of 560 nm .

During exposure the orange fruits of fourth maturity stage has turning color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 2455.97 and 2446.66 a.u. at wavelength 559 and 561nm, respectively. Meanwhile, it was found the peak (2461.68 a.u) of reflection intensity at wavelength of 560 nm . Also, it was found the absorption intensity from the same stage of orange fruits was found around 2608.18 and 2590.01a.u. at wavelength 569 and 571nm, respectively. Meanwhile, it was found the peak (2615.14 a.u) of absorption intensity at wavelength of 570 nm .

During exposure the orange fruits of fifth maturity stage has yellow color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 3757.94 and 3745.84 a.u. at wavelength 569 and 571 nm, respectively. Meanwhile, it was found the peak (3760.96 a.u.) of reflection intensity at wavelength of 570 nm. Also, it was found the absorption intensity from the same stage of orange fruits was found around 3176.24 and 3167.86 a.u. at wavelength 579 and 581nm, respectively. Meanwhile, it was found the peak (3189.04 a.u) of absorption intensity at wavelength of 580 nm .

During exposure the orange fruits of sixth maturity stage has orange color were found the highest reflection intensities. The reflection intensity from the first stage of orange fruits was found around 3584.32 and 3349.31 a.u. at wavelength 579 and 581 nm, respectively. Meanwhile, it was found the peak (3610.12 a.u) of reflection intensity at wavelength of 580 nm . Also, it was found the absorption intensity from the same stage of orange fruits was found around 3837.25 and 3814.44 a.u. at wavelength 584 and 586nm, respectively. Meanwhile, it was found the peak (3840.15 a.u) of absorption intensity at wavelength of 585 nm .

The obtained results to exposure orange fruit for visible wavelengths 400 700 nm were showed that the reflection intensity was ranged from 1039.24 to 3760.96 a.u. Meanwhile, by using the same visible wavelengths to measure absorption intensities in orange fruits at different maturity stages, the data indicated to absorption intensity were ranged from 593.93 to 3840.15 a.u. The light reflection and absorption intensities had clearly variances between them at using visible light with wavelengths (400 - 700 nm). Therefore, measurements of reflection and absorption intensities were possible to use wavelengths of 400 -700 nm for measuring quality of orange fruits at different maturity stages.

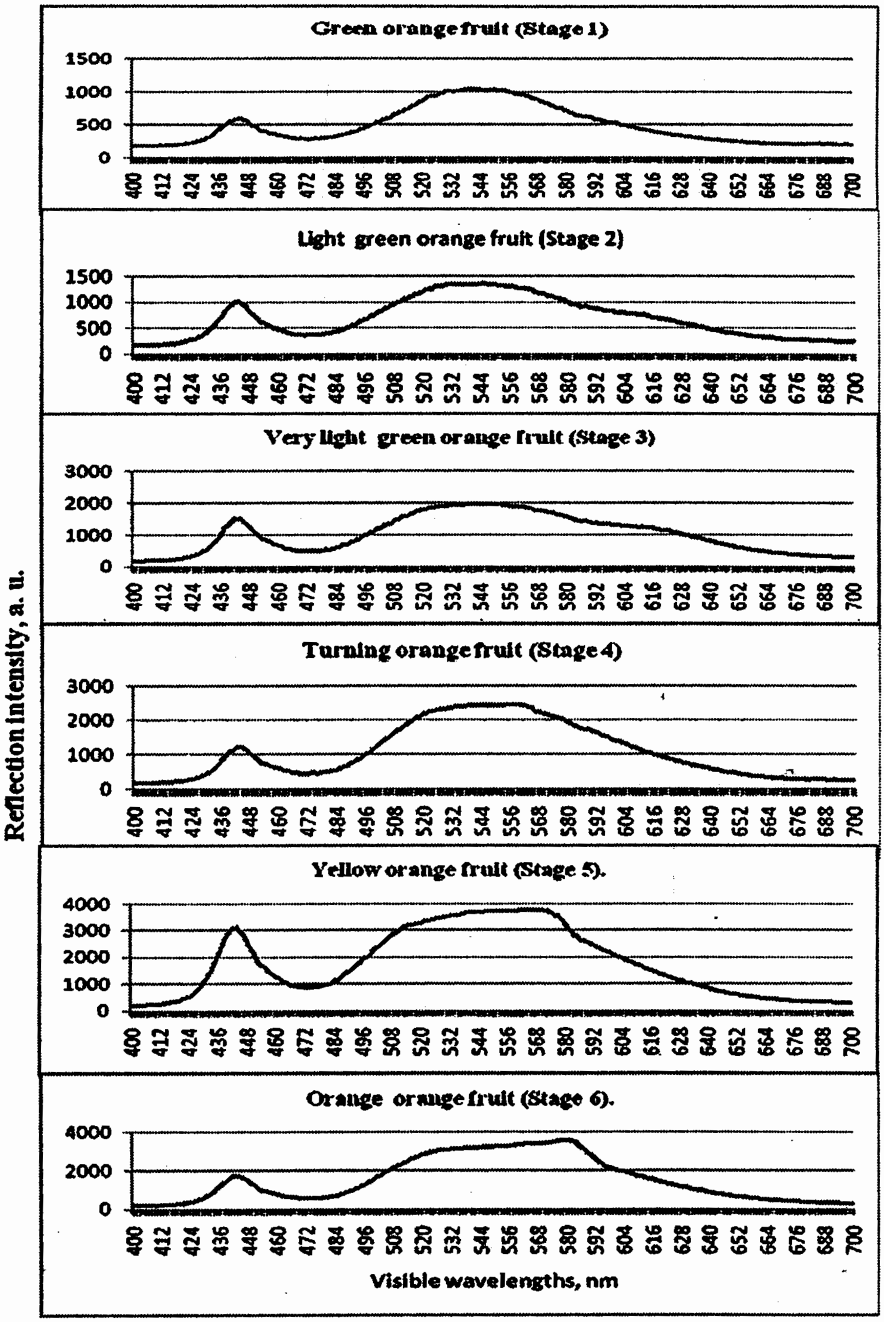


Fig. (6) : Reflection intensity of visible light from orange fruits at different maturity stages.

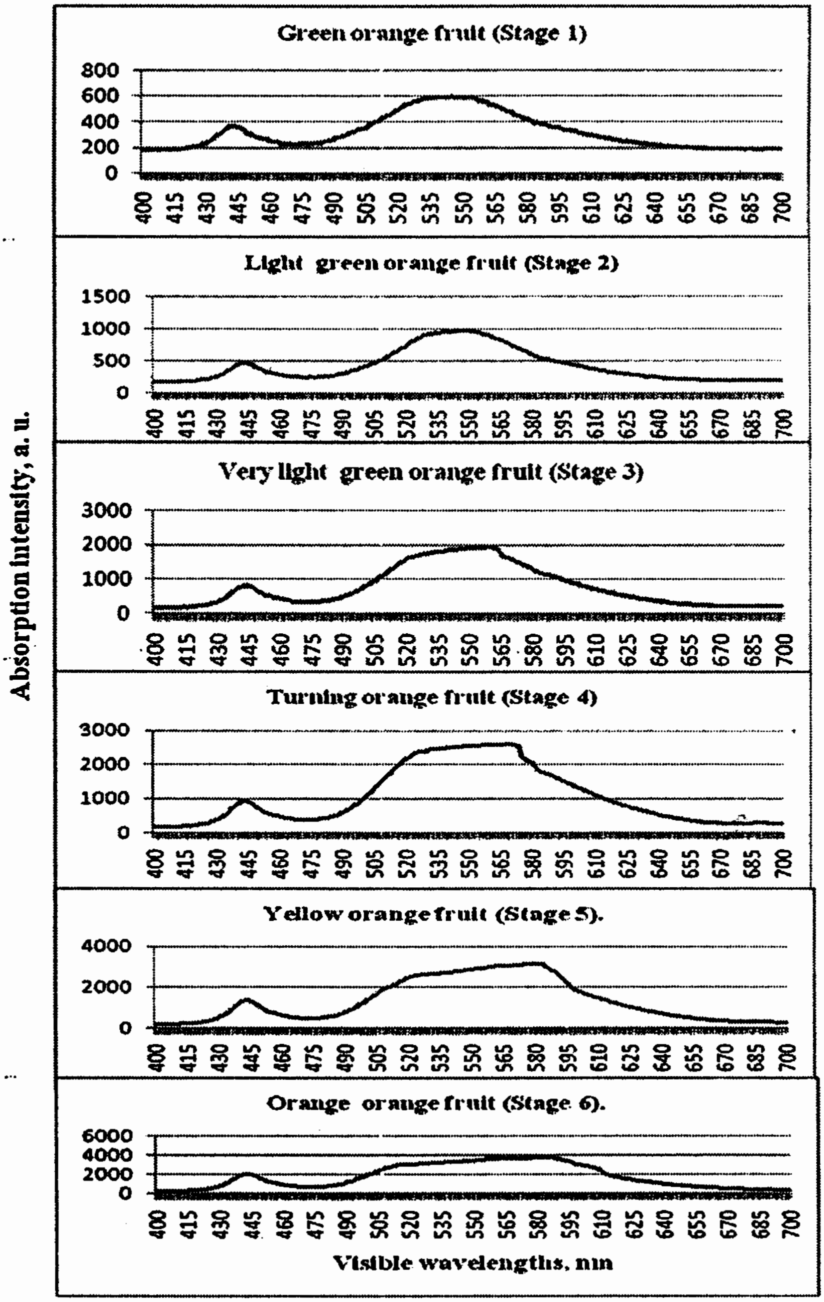


Fig. (7) : Absorption intensity of visible light from orange fruits at different maturity stages.

So, it was considered the peak intensity 1051.83, 1361.42, 1959.85, 2461.68, 3760.96 and 3610.12 a.u. of wavelengths 540, 545, 550, 560, 570 and 580 nm for green, light green, very light green, turning, yellow, and orange color of orange fruit, respectively, as a suitable wavelengths for detect collect time during harvesting season of orange fruit through maturity stages. Also, it can be use sorting and grading machine as source of detection optical properties for orange fruit at different maturity stages.

CONCLUSION

The obtained results are summarized as follows:

- The light reflection and absorption intensities of ultraviolet light from different maturity stages ranged between (173.8-188.80 a.u.) and (174.29-188.80 a.u.) for wavelengths from 350 to 400 nm, respectively.
- The light reflection and absorption intensities of infrared light from different maturity stages ranged between (166.72-277.73 a.u.) and (172.01-290 a.u.) for infrared wavelengths from 700 to 1000 nm, respectively.
- The light reflection and absorption intensities didn't have clearly differences between them when using ultraviolet with wavelengths (350-400 nm) and infrared with wavelengths (700–1000 nm);
- The peak reflection intensities using visible light were found 1051.83, 1361.21, 1959.85, 2461.68, 3760.96, 3189.04, and 3610.12 a.u at wavelengths of 540, 545, 550, 560, 570, 580 nm, respectively. Meanwhile, the peak absorption intensities were found 598.12, 980.79, 1959.73, 2615.14, 3189.04 and 3840.15 a.u at wavelengths of 545 , 550, 560, 570, 580, and 585 nm for green, light green , very light green and turning, yellow, and orange maturity stages of orange fruit colors, respectively., as a measuring to detect maturity stages of orange fruits.,
- Using light spectrum with wavelengths from 540 to 585 nm is preferable in grading orange fruit as a source of reflection and absorption peaks during maturity stages and can automatically control the process., and
- The peak reflection intensities at visible wavelengths can be used as suitable wavelength to detect optical characteristics of orange fruits for collecting time in harvesting season, and in industrial sorting and grading machine according to maturity stages.

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الملخص العربي

التنبؤ بالطول الموجى المناسب لمراحل نضج ثمار البرتقال باستخدام التحليل الطيفى

عبدالرحمن عبدالرؤف عبدالرحمن *

تهدف هذه الدراسة إلى إجراء بعض التجارب والقياسات لتحديد الخواص الضوئية للمراحل المختلفة لثمار البرتقال الناضج صنف بلدى (أبوسره) باستخدام شعاع التحليل الطيفى. حيث استخدمت. ثلاث مناطق الضوء وهى الأشعة المرئيه (٤٠٠ ٧٠٠ نانوميتر)، والأشعة غير المرئية (تحت الحمراء من٧٠٠ الى ١٠٠٠ نانومتر ، الأشعة فوق البنفسجية من٤٠٠ الى ٣٥٠نانومتر). . وتم إجراء التجارب والقياسات بمعمل تطبيقات الليزر فى الهندسة الزراعية بالمعهد القومى لعلوم الليزر، جامعة القاهرة وذلك بإنشاء جهاز تجريبى لقياس الخصائص الضوئية للثمار حيث تم قياس الكثافة الضوئية المنعكسة من سطح الثمار والكثافة الضوئية الممتصة فى ثمار البرتقال لمراحل النضج المختلفة (٦ لون) باستخدام التحليل الطيفى) .. وكانت النتائج المتحصل عليها على النحو التالي :

١) الكثافة الضوئية المنعكسة باستخدام الأشعة فوق بنفسجية من ٣٥٠ الى ٤٠٠ نانومتر من سطح ثمار البرتقال عند مراحل النضج المختلفة تراوحت بين ١٧٣،٨٠و١٨٨،٨٠ .a.u بينما تراوحت الكثافة الضوئية الممتصة بين ١٧٤،٢٩-١٨٨،٨٠ .a.u.

٢) الكثافة الضوئية المنعكسة باستخدام الأشعة تحت الحمراء من ٧٠٠ الى ١٠٠٠ نانومتر من سطح ثمار البرتقال عند مراحل النضج المختلفة تراوحت بين بين ١٦٦،٧٢ – ٢٧٧،٧٣ .a.u بينما تراوحت الكثافة الضوئية الممتصة بين ١٧٢،٠١-٢٩٠،٠٠ .a.u، ولذلك لا يوجد اختلاف كبيرة بين قيم الكثافات الضوئية المنعكسة وبعضها ، وبين الكثافات الممتصة وبعضها من سطح ثمار البرتقال عند مراحل النضج المختلفة باستخدام الأشعة فوق البنفسجية وتحت الحمراء ذات الأطوال الموجية المختلفة ، وبذلك أهملت قياسات الأشعة المنعكسة والممتصة باستخدام الأشعة فوق البنفسجية وتحت الحمراء .

٣) أعلى كثافه ضوئيةً منعكسة باستخدام الأشعة المرئية بأطوال موجية ٤٠٠ – ٧٠٠ نانوميتر كانت ١٠٥١،٨٣، ١٣٦١،٢١، ١٩٥٩،٨٥، ٢٤٦١،٦٨، ٣٧٦٠،٩٦، ٣٦١٠،١٢ .a.u باستخدام الأطوال الموجية ٥٤٠، ٥٤٥، ٥٥٠، ٥٦٠، ٥٧٠، ٥٨٠ نيوتن متر على التوالي. بينما كانت أعلى كثافه ضوئية ممتصة باستخدام نفس مدى الأشعة المرئية ٥٩٨،١٢، ٩٨٠،٧٩، ١٩٥٩،٧٣، ٢٦١٥،١٤، ٣١٨٩،٠٤ ، ٣٨٤٠،١٥ .a.u باستخدام الأطوال الموجية ٥٤٥، ٥٥٠، ٥٦٠، ٥٧٠، ٥٨٠، ٥٨٥ نانومتر لمراحل نضج ثمار البرتقال الأخضر، أخضر فاتح، أخضر فاتح جدا ، المتحول، الأصفر، والبرتقالى على التوالي.

٤) يمكن استخدام الأطوال الموجية ٥٤٠، ٥٤٥، ٥٥٠، ٥٦٠، ٥٧٠، ٥٨٠ نانومتر كمصدر للحصول على أعلى كثافة ضوئية منعكسة بينما تستخدم الأطوال الموجية ٥٤٥، ٥٥٠، ٥٦٠، ٥٧٠، ٥٨٠ ، و ٥٨٥ نانومتر كمصدر للحصول على أعلى كثافة ضوئية ممتصة لمراحل نضج ثمار البرتقال الأخضر، أخضر فاتح، أخضر فاتح جدا ، المتحول، الأصفر، والبرتقالى على التوالي ، كمقياس التنبؤ بمراحل نضج ثمار البرتقال وجودتها.

٥) يمكن استخدام موجات الطيف الضوئي من ٥٤٠ الى ٥٨٥ نانومتر كمدى مفضل في تدريج ثمار البرتقال كمصدر لأعلى كثافة ضوئية منعكسه وممتصة خلال مراحل النضج لثمار البرتقال وفى نظم التحكم الآلى لعمليات الجودة بهدف تداول الثمار محليا وخارجيا.

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